

WHAT WE CLAIM ARE

1. A method of manufacturing a semiconductor device, comprising the steps of:

(a) forming a first insulating film above a semiconductor substrate

formed with semiconductor elements;

(b) forming a contact hole through the first insulating film;

(c) forming a plug made of conductive material capable of being nitrided,
the plug being embedded in the contact hole; and

(d) heating the semiconductor substrate in a nitriding atmosphere to
nitride the plug from a surface thereof.

2. A method of manufacturing a semiconductor device according to claim 1, wherein
the conductive material is W.

3. A method of manufacturing a semiconductor device according to claim 2, wherein
said step (d) is executed at a temperature range of 600 °C to 850 °C in an atmosphere
containing ammonia.

4. A method of manufacturing a semiconductor device according to claim 1, further
comprising the step of:

(e) forming an etch stopper layer on the first insulating film, the etch
stopper layer covering the plug.

5. A method of manufacturing a semiconductor device according to claim 4, wherein
said step (e) includes a step of heating the semiconductor substrate and supplying
SiN source gas to the semiconductor substrate to form an SiN layer on the first
insulating film through chemical vapor deposition, the SiN layer covering the plug.

6. A method of manufacturing a semiconductor device according to claim 5, further comprising the steps of:

(f) forming a second insulating film on the SiN layer;

5 (g) forming an opening through the second insulating film, the opening reaching the surface of the plug; and

(h) forming a rare metal layer in the opening, first through physical vapor deposition not using oxygen and then through chemical vapor deposition using oxygen.

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7. A semiconductor device comprising:

a semiconductor substrate formed with semiconductor elements;

an inter-level insulating film formed above said semiconductor substrate;

and

15 a WN plug passing through the insulating film, a nitrogen concentration of said WN plug lowering from a surface of said WN plug toward a deeper position.

8. A method of manufacturing a semiconductor device, comprising the steps of:

20 (a) forming a lower electrode above a semiconductor substrate formed with semiconductor elements, the lower electrode having a top surface and side surfaces;

(b) forming a dielectric film on a surface of the lower electrode, the dielectric film being relatively thick in a region near a boundary between the top surface and each of the side surfaces and relatively thin and generally uniform in a
25 lower region of the side surfaces; and

(c) forming an upper electrode on the dielectric film.

9. A method of manufacturing a semiconductor device according to claim 8, wherein the lower electrode has a cylinder shape with an inner and an outer side surface, and the dielectric film extends from the inner side surface of the cylinder via the top surface to the outer side surface of the cylinder.

10. A method of manufacturing a semiconductor device according to claim 8, wherein said step (b) includes a combination of a step of forming a film with a good step coverage and a step of forming a film with a poor step coverage.

11. A method of manufacturing a semiconductor device according to claim 10, wherein said step of forming a film with a poor step coverage is executed by physical vapor deposition, surface reaction limited chemical vapor deposition, low pressure chemical vapor deposition at a pressure of about 1 Torr or higher, or a combination thereof.

12. A method of manufacturing a semiconductor device according to claim 8, wherein the lower electrode is made of rare metal, and said step (a) forms the lower electrode on an underlie surface exposing a plug made of material capable of being oxidized, and includes a step of forming a film under a condition not using oxygen and a step of forming a film under a condition using oxygen.

13. A method of manufacturing a semiconductor device according to claim 8, wherein said step (c) includes a step of depositing a lower part of the upper electrode made of rare metal through chemical vapor deposition under a condition containing oxygen at a first concentration and a step of depositing an upper part of the upper electrode made

of rare metal through chemical vapor deposition under a condition containing oxygen at a concentration lower than the first concentration.

14. A semiconductor device comprising:

5 a semiconductor substrate formed with semiconductor elements;
 a lower electrode disposed above a surface of said semiconductor substrate and having a top surface and side surfaces;

 a dielectric film formed on a surface of said lower electrode, said dielectric film being relatively thick in a region near a boundary between the top
10 surface and each of said side surfaces and relatively thin and generally uniform in a lower region of each of the side surfaces; and

 an upper electrode formed on said dielectric film.

15. A method of manufacturing a semiconductor device, comprising the steps of:

15 (a) forming a rare metal layer above a semiconductor substrate formed with semiconductor elements;

 (b) forming an insulating mask layer on the rare metal layer;

 (c) patterning the insulating mask layer by using a resist pattern; and

20 (d) patterning the rare metal layer by using the patterned insulating mask layer.

16. A method of manufacturing a semiconductor device according to claim 15, wherein the insulating mask layer is made of at least one of TaO, alumina, NbO, TiO, and SiO.

25 17. A method of manufacturing a semiconductor device according to claim 16, further

comprising a step of:

(e) forming a metal nitride layer on the rare metal layer after said step (a) and before said step (b),

wherein said step (c) is terminated before the rare metal layer is

5 exposed and said step (d) patterns the metal nitride layer and the rare metal layer by using the patterned insulating mask layer.

18. A method of manufacturing a semiconductor device according to claim 17,

wherein said step (e) forms the metal nitride layer without using hydrogen-containing

10 gas or hydrogen-containing atmosphere.

19. A method of manufacturing a semiconductor device according to claim 15, further comprising the steps of:

(f) forming an insulating film over the semiconductor substrate, the
15 insulating film covering the insulating mask layer; and

(g) annealing the semiconductor substrate in hydrogen-containing gas.

20. A method of manufacturing a semiconductor device according to claim 19,

wherein said step (f) forms a silicon oxide film by TEOS based CVD.

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21. A semiconductor device comprising:

a semiconductor substrate with semiconductor elements;

a rare metal layer disposed above said semiconductor substrate; and

a TaO film disposed on said rare metal layer, said TaO layer having a

25 same plan shape as said rare metal layer.